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US 5105435 A

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UK CL (Edition L) H4L LFND LFNX, H4P PAN
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(54) Threshold cancellation means for use in digital mobile radio networks

(57) In a direct sequence spread spectrum code division multiple access receiver using interference cancellation, the signal for cancellation is derived by demodulating the unwanted signals and re-modulating a carrier to create a near replica for subtraction from a delayed version of the total received signal. Errors in the demodulation process degrade the cancellation. The present invention provides an optimal way of using the reliability information in the demodulator decision variable either to get the cancellor off for unreliable bit decisions or to partially disable the cancellor according the bit reliabilities.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

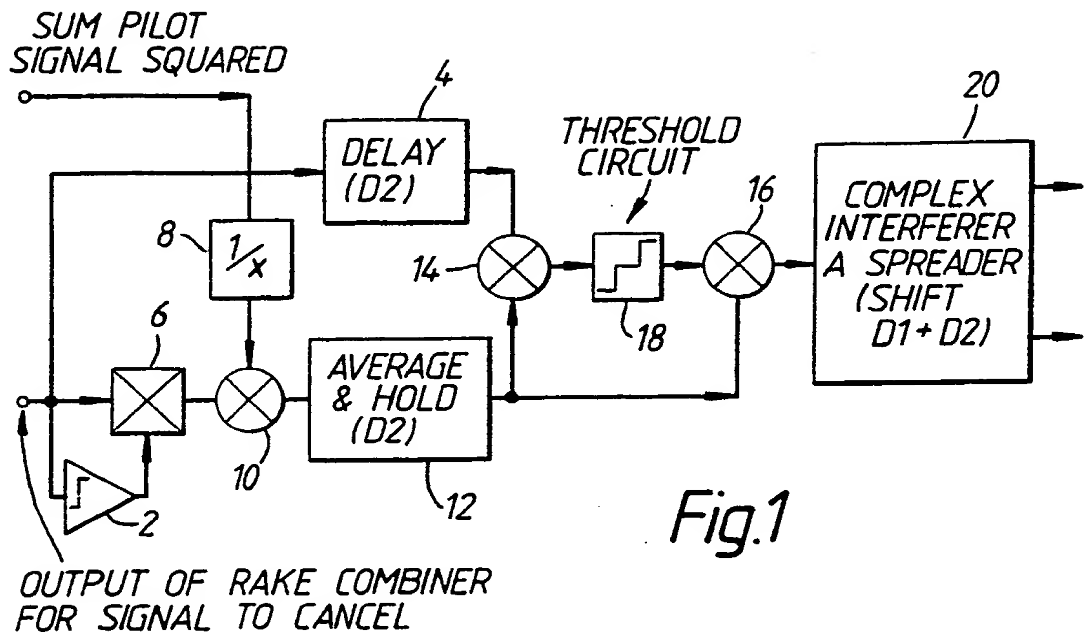
SUM PILOT
SIGNAL SQUARED
4
DELAY
(D2)
20
THRESHOLD
CIRCUIT
16
COMPLEX
INTERFERER
A SPREADER
(SHIFT
D1+D2)
8
1/x
14
18
6
AVERAGE
& HOLD
(D2)
10
12
2
OUTPUT OF RAKE COMBINER
FOR SIGNAL TO CANCEL

Fig.1

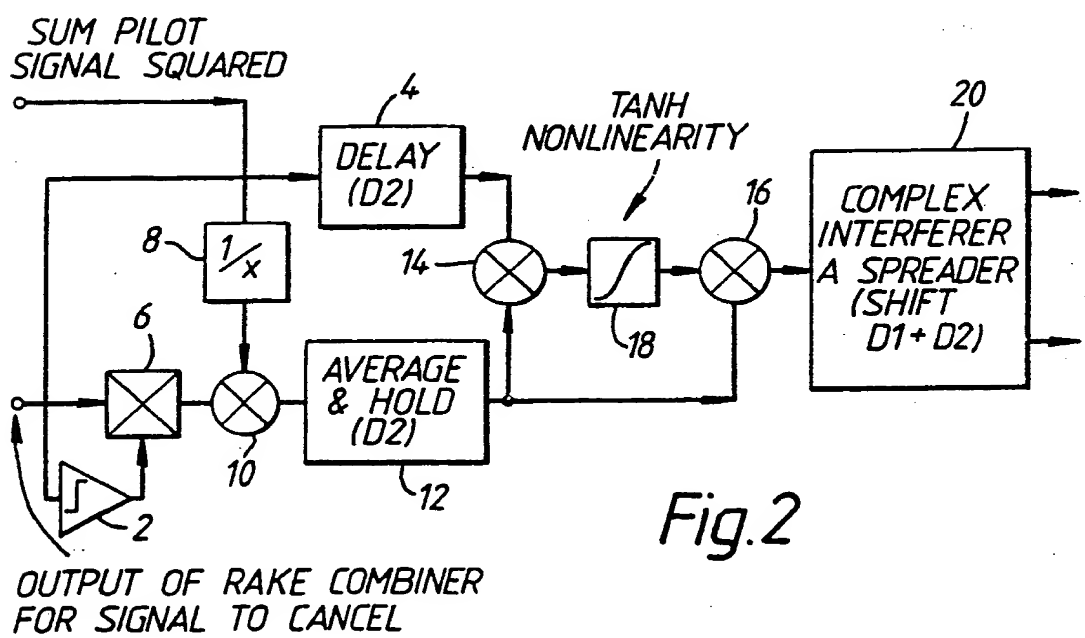
SUM PILOT
SIGNAL SQUARED
4
DELAY
(D2)
20
TANH
NONLINEARITY
16
COMPLEX
INTERFERER
A SPREADER
(SHIFT
D1+D2)
8
1/x
14
18
6
AVERAGE
& HOLD
(D2)
10
12
2
OUTPUT OF RAKE COMBINER
FOR SIGNAL TO CANCEL

Fig.2

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THRESHOLD CANCELLATION MEANS FOR USE IN DIGITAL MOBILE RADIO NETWORKS

The present invention relates to threshold cancellation means for use in digital mobile radio networks of the type wherein a number of base stations communicate with a number of mobile radio units each being temporarily affiliated to a particular base station.

The present invention relates directly to interference cancellation in a direct sequence spread spectrum (DSSS) code division multiple access (CDMA) scheme. Any unwanted signals are demodulated and the recovered data along with the channel information is derived from a pilot signal and is used to create a near replica of the unwanted signal for cancellation. Cancellation can be very effective if the code phase, carrier phase and amplitude of the significant multipath components of the interfering signal are known, provided correct decisions are taken on the data modulating the unwanted signal. Whenever an incorrect decision is taken, far from cancelling the interference the circuit will increase it. For example, if the interference RMS voltage is A volts, then the optimum cancellation would be an equal and opposite, reconstructed signal, also of A volts. However, when an error is made, the output of the cancellation means will not be zero but 2A volts, ie. four times the power which would have been received if cancellation had not been applied. In this

situation it would have been better not to have attempted to cancel the interference.

Accordingly, an object of the present invention is to provide cancellation means which can be turned off whenever incorrect decisions become likely.

A further object of the present invention is to provide cancellation means which may be partially turned off whenever incorrect decisions become likely.

According to the present invention there is provided cancellation means including means for receiving an output signal from a Rake combiner, means for receiving and scaling a pilot signal, first multiplying means for generating signal comprising a product of the scaled pilot signal and a modified output signal, an average and hold device for receiving the output signal generated by said first multiplying means, second multiplying means for combining a signal generated from the average and hold device with a delayed output signal, threshold means arranged to switch the cancellation means on or off to permit or prevent an output signal from the second multiplying means from being applied to weighting means and interference spreading means.

Embodiments of the present invention will now be described with reference to the accompanying drawings in which;

FIGURE 1 shows a block diagram of a cancellation means having optimum thresholding, and

FIGURE 2 shows a block diagram of a cancellation means having optimum non-linearity.

Consider a known short term signal rms voltage, A with modulation for the kth symbol, m_k which is either +1 (for a transmitted '1') or -1 (for a transmitted '0'). The signal is received in the presence of noise with variance, σ. The demodulator makes decisions d_k which match m_k when correct. Thus the signal energy component at the output of the cancellor (when active) for the kth symbol is given by:

$$C_{out}(active)_k = A^2(m_k - d_k)^2$$

The probability distribution of the received voltage, R is given by:

$$P(R) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left\{-\frac{(R - m_k.\sqrt{2}.A)^2}{2\sigma^2}\right\}$$

For a given particular value, r of R it is desirable to know whether it is better to cancel or not. The problem is that it is not known whether a 1 or 0 was transmitted. The reliability of the decision will depend on the modulus of r. Therefore,

$$P(r|1) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left\{-\frac{(r - \sqrt{2}.A)^2}{2\sigma^2}\right\} \text{ and}$$

$$P(r|0) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left\{-\frac{(r + \sqrt{2}.A)^2}{2\sigma^2}\right\}$$

Using Baye's rule and solving for $| r |$ gives:

$$|r| = \frac{\sigma^2.(\log_e 3)}{2\sqrt{2}.A}$$

This implies a threshold which must adapt to the mean levels of noise and signal. A simpler solution is to weight the signal before applying to a fixed threshold, ie.:

$$\frac{A}{\sigma^2}.|r| = \frac{\log_e 3}{2\sqrt{2}}$$

This requires normalising the signal. The noise power out of the Rake combiner is proportional to the pilot energy, ie.:

$$\sigma_t^2 = \sigma_c^2 P^2.k^2 \sum_{i=0}^{N-1} a_i^2$$

Where σ_c is the unweighted noise voltage out of any of the correlators. The multiplier is exactly the sum of the squares of the pilot signals as applied to the scaling circuit in Figure 4 of co-pending patent application number 9313078.9. Thus, normalisation of the r by $1/\sigma^2$, requires division by this scaling signal, as already performed in Figure 4 of the above mentioned patent application. In Figure 4, the scaling is performed on a decision corrected signal to obtain a mean signal level. Thus the

output of the average and hold circuit in Figure 1 is proportional to $\frac{A}{\sigma^2}$ and is the correct scale for r.

Referring to Figure 1, a block diagram is shown for the thresholding cancellation means.

The threshold and cancellation means comprises a hard limiting device 2 which receives at an input thereof an output signal from a Rake combiner which requires cancellation. The hard limiting device 2 performs decisions on the interferer's data which are used to reconstruct the interferer for the purpose of subtraction, ie. cancellation. The output from the Rake combiner is also connected to an input of a delay circuit 4, and to an input of a combiner circuit 6. A scaling device 8 receives a summed and squared pilot signal from the Rake combiner and has an output connected to an input of a multiplying circuit 10. An output from the combiner circuit 6 is connected to a further input of the multiplying circuit 10. An output from the multiplying circuit 10 is connected to an input of an average and hold device 12, the output of which is connected to an input of two further multiplying circuits 14 and 16. An output from the delay circuit 4 is connected to a further input of the multiplying circuit 14 and an output thereof is connected to an input of a threshold circuit 18. An output from the threshold circuit 18 is connected to a further input of the multiplying circuit 16, which has an output connected to an input of a complex interferer A spreader 20. The spreader 20 is provided with two output lines which are connected to

further circuitry as shown in Figure 4 of the above mentioned patent application.

The threshold circuit 18 performs a bi-directional thresholding, since the requirement is to subtract a fixed voltage (weighted in the following circuit) which has the same sign as the instantaneous signal whenever the modulus of the instantaneous signal exceeds a threshold. In this manner, the cancellation means is turned on or off. Any constant terms required in the multiplications are assumed to be hardwired into the scaling employed.

For a signal to noise ratio of 0 dB, an improvement in cancellation of about 0.85 dB can be achieved.

Further improvements can be obtained if the cancellation means is turned partially on or off according to the reliability of the decisions.

This can be achieved by weighting the cancelling signal according to the reliability of the decisions, ie. according to r. Thus the weighting term is a function of r, k(r). For a given value of r, we have:

$$Cout.k = A^2 \left\{ (m_k - d_k.k(|r|))^2 \right\}$$

Now if a correct decision is made, $m_k = d_k$ and $Cout.k = A^2.(1-k(|r|)^2$. If an incorrect decision is made $m_k \neq d_k$ and $Cout.k = A^2.(1+k(|r|)^2$. Therefore:

$$E\{Cout\} = A^2\{(1 - k(|r|))^2.(1 - Pe) + (+ k(|r|))^2.Pe\}$$
$$= A^2\{1 - 2.k(|r|).(1 - 2.Pe) + k^2(|r|)\}$$

Differentiating with respect to k(| r |) to obtain:

$$\frac{dE\{Cout\}}{dk(|r|)} = A^2\{2k(|r|) - 2(1 - 2.Pe)\}$$

Set to zero to find minimum:

$$k(|r|)=1-2P_e=\frac{1+\exp\left\{\frac{2.\sqrt{2}.A|r|}{\sigma^2}\right\}-2}{1+\exp\left\{\frac{2.\sqrt{2}.A|r|}{\sigma^2}\right\}}=\frac{\exp\left\{\frac{2.\sqrt{2}.A|r|}{\sigma^2}\right\}-1}{\exp\left\{\frac{2.\sqrt{2}.A|r|}{\sigma^2}\right\}+1}$$

$$k(|r|) = \tanh\left\{\frac{\sqrt{2}.A|r|}{\sigma^2}\right\}$$

The normalisation against $\frac{A}{\sigma^2}$ is as for the thresholding circuit. The decision, d_k may be taken into the tanh non-linearity by removing the modulus operator. The circuit for applying the optimum non-linearity is shown in Figure 2.

The non-linearity obtained by Figure 2 increases mean interference cancellation by about 1.35 dB at 0 dB signal to noise ratio.

With reference to Figure 2, it would be seen that the circuit is substantially identical with that of Figure 1 and therefore

further description is deemed not to be necessary. However the threshold circuit 18 is now arranged to perform a Tanh non-linearity function which allows the cancellation means to be partially switched on and off.

CLAIMS

1. Cancellation means including means for receiving an output signal from a Rake combiner, means for receiving and scaling a pilot signal, first multiplying means for generating signal comprising a product of the scaled pilot signal and a modified output signal, an average and hold device for receiving the output signal generated by said first multiplying means, second multiplying means for combining a signal generated from the average and hold device with a delayed output signal, threshold means arranged to switch the cancellation means on or off to permit or prevent the output signal from the second multiplying means from being applied to weighting means and interference spreading means.

2. Cancellation means as claimed in Claim 1, wherein the threshold means is arranged to turn the cancellation means partially on or off.

3. Cancellation means substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

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Application number

GB 9313609.1

Relevant Technical fields

(i) UK Cl (Edition L) H4L (LFND, LFNX) H4P (PAN)

(ii) Int Cl (Edition 5) H04B 1/12

Databases (see over)

(i) UK Patent Office

(ii) ONLINE: WPI

Search Examiner

N W HALL

Date of Search

20 SEPTEMBER 1993

Documents considered relevant following a search in respect of claims 1-3

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	US 5105435 (STILWELL)	

SF2(p)

swA - doc99\fil001649

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

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&: Member of the same patent family, corresponding document.

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